

CLAIMS

We Claim:

1. A spatial light modulator, comprising:
 - a substrate that is transmissive to visible light;
 - a silicon substrate;
 - wherein the silicon substrate and the substrate that is transmissive to visible light are bonded together with a spacer therebetween forming a gap between the substrates; and
 - a plurality of deflectable elements encapsulated within the gap.
2. The spatial light modulator of claim 1, wherein deflectable elements are microelectromechanical deflectable elements.
3. The spatial light modulator of claim 1, wherein the distance between the substrates is from 1 to 5 microns.
4. The spatial light modulator of claim 1, wherein the substrate that is transmissive to visible light further comprises:
 - a dielectric layer.
5. The spatial light modulator of claim 4, wherein the substrate that transmissive to visible light further comprises:
 - another dielectric layer, wherein said another dielectric layer has an optical index different from that of the dielectric layer.
6. The spatial light modulator of claim 1, wherein the substrate that is transmissive to visible light is glass.
7. The spatial light modulator of claim 1, wherein the substrate that is transmissive to visible light is quartz.
8. The spatial light modulator of claim 1, further comprising:

a first pattern on the substrate that is transmissive to visible light;
a second pattern on the silicon substrate; and
wherein the first and second patterns are aligned together when the substrates are bonded together.

9. The spatial light modulator of claim 1, wherein the spacer is surrounded by a plurality of deflectable elements; and wherein each of the plurality of deflectable elements has an edge coplanar with a corresponding edge of the spacer.

10. The spatial light modulator of claim 1, wherein the spacer is positioned within the plurality of deflectable elements.

11. The spatial light modulator of claim 1, wherein the substrates are bonded together with the spacer therebetween using an adhesive.

12. The spatial light modulator of claim 11, wherein the adhesive is epoxy.

13. The spatial light modulator of claim 1, wherein the substrates are aligned together such that each deflectable element is aligned with an electrode.

14. The spatial light modulator of claim 1, wherein the spacer is positioned outside the plurality of deflectable elements.

15. The spatial light modulator of claim 1, wherein the deflectable elements are mirror plates.

16. The spatial light modulator of claim 1, where in the deflectable element comprises a ceramic material.

17. The spatial light modulator of claim 16, wherein the ceramic material is silicon dioxide or silicon nitride.

18. The spatial light modulator of claim 17, wherein the deflectable element comprises a light reflection layer.
19. The spatial light modulator of claim 15, wherein each mirror plate is attached to a hinge such that the mirror plate is operable to rotate.
20. The spatial light modulator of claim 19, wherein the hinge is a torsion hinge.
21. The spatial light modulator of claim 19, wherein the mirror plate comprise a first and second portions such that during the rotation of the mirror plate, the second portion moves towards the glass substrate and the first portion moves away from the glass substrate; and wherein the hinge and the mirror plate are positioned in different planes.
22. A spatial light modulator, comprising:
 - a first substrate having a plurality of micromirrors and a spacer that is positioned within the plurality of micromirrors; and
 - a second substrate having an array of electrodes and circuitry, wherein the first and second substrates are bonded together with the spacer between the first and second substrates.
23. The spatial light modulator of claim 22, wherein the first substrate is transmissive to visible light; and wherein the second substrate is a silicon substrate.
24. The spatial light modulator of claim 23, wherein the first substrate is glass.
25. The spatial light modulator of claim 23, wherein the first substrate is quartz.
26. The spatial light modulator of claim 22, wherein the distance between the substrates is from 1 to 5 microns.

27. The spatial light modulator of claim 23, wherein the first substrate further comprises:

a dielectric layer.

28. The spatial light modulator of claim 27, wherein the first substrate further comprises:

another dielectric layer, wherein said another dielectric layer has an optical index different from that of the dielectric layer.

29. The spatial light modulator of claim 23, further comprising:

a first pattern on the first substrate;

a second pattern on the second substrate; and

wherein the first and second patterns are aligned together when the substrates are bonded together.

30. The spatial light modulator of claim 22, wherein the spacer is surrounded by a plurality of micromirrors, each of which has an edge coplanar with a corresponding edge of the spacer.

31. The spatial light modulator of claim 22, wherein the substrates are bonded together with the spacer in between using with an adhesive.

32. The spatial light modulator of claim 31, wherein the adhesive is epoxy.

33. The spatial light modulator of claim 22, where in the micromirror comprises a ceramic material.

34. The spatial light modulator of claim 33, wherein the ceramic material is silicon dioxide or silicon nitride.

35. The spatial light modulator of claim 22, wherein the micromirror comprises a light reflection layer.

36. The spatial light modulator of claim 35, wherein each micromirror has a mirror plate that is attached to a hinge such that the mirror plate is operable to rotate along a rotation axis.

37. The spatial light modulator of claim 36, wherein the hinge is a torsion hinge.

38. The spatial light modulator of claim 36, wherein the mirror plate comprise a first and second portions such that during the rotation of the mirror plate, the second portion moves towards the glass substrate and the first portion moves away from the glass substrate; and wherein the mirror plate and the hinge are positioned in different planes.

39. A spatial light modulator, comprising:

a first substrate;

a second substrate, wherein the first and the second substrates are bonded together with a spacer therebetween so as to form a gap between the substrates; and

a plurality of micromirrors positioned within the gap, each micromirror further comprising:

a mirror plate, further comprising:

a first and second portions, wherein the second portion moves away from the first substrate when the first portion moves towards the first substrate;

a hinge that is located in a plane other than a plane in which the mirror plate is located; and

wherein the mirror plate is attached to the hinge such that the mirror plate is operable to rotate.

40. The spatial light modulator of claim 39, wherein the distance between the substrates is from 1 to 5 microns.

41. The spatial light modulator of claim 39, wherein the first substrate is transmissive to visible light.
42. The spatial light modulator of claim 41, where in the first substrate further comprises:
 - a dielectric layer.
43. The spatial light modulator of claim 41, wherein the first substrate is glass.
44. The spatial light modulator of claim 41, wherein the first substrate further comprises:
 - another dielectric layer, wherein said another dielectric layer has an optical index different from that of the dielectric layer.
45. The spatial light modulator of claim 41, wherein the second substrate is silicon.
46. The spatial light modulator of claim 45, further comprising:
 - a first pattern on the first substrate;
 - a second pattern on the second substrate; and
 - wherein the first and second patterns are aligned together when the substrates are bonded together.
47. The spatial light modulator of claim 39, wherein the spacer is surrounded by a plurality of micromirrors; and wherein each of said plurality of micromirrors has an edge coplanar with a corresponding edge of the spacer.
48. The spatial light modulator of claim 39, wherein the substrates are bonded together with the spacer therebetween using an adhesive.
49. The spatial light modulator of claim 48, wherein the adhesive is epoxy.

50. The spatial light modulator of claim 39, wherein the substrates are aligned together such that each micromirror is aligned with an electrode.
51. The spatial light modulator of claim 39, wherein the spacer is positioned outside the plurality of micromirrors.
52. The spatial light modulator of claim 39, where in the micromirror comprises a ceramic material.
53. The spatial light modulator of claim 52, wherein the ceramic material is silicon dioxide or silicon nitride.
54. The spatial light modulator of claim 52, wherein the mirror plate of the micromirror comprises a light reflection layer.
55. The spatial light modulator of claim 54, wherein the hinge is a torsion hinge.
56. A method of modulating light, comprising:
 - providing a spatial light modulator that comprises a first and second substrates, the first substrate being optically transmissive and being held above the second substrate, an electrostatically deflectable mirror suspended by a hinge from the optically transmissive substrate, the second substrate containing an electrode and circuitry;
 - providing an incoming light beam that passes through the optically transmissive substrate and that is reflected by the electrostatically deflectable mirror;
 - applying a voltage bias between the mirror and the electrode so as to deflect the mirror due to electrostatic attraction; and
 - deflecting the light beam back through the optically transmissive substrate.
57. The method of claim 56, wherein the second substrate is a silicon substrate, and the electronic circuitry is electrical addressing circuitry.

58. The method of claim 57, wherein the silicon substrate is a VLSI-fabricated silicon substrate.

59. The method of claim 57, wherein the silicon substrate resembles a low-density DRAM.

60. The method of claim 57, wherein the deflectable mirror is a mirror made of a film deposited as part of a process incompatible with VLSI processes.

61. The method of claim 56, wherein the deflectable mirror is deflected using a MOS transistor on the second substrate.

62. The method of claim 56, wherein the addressing circuitry resembles a memory array.

63. A method of making a spatial light modulator, comprising:
forming a plurality of micromirrors on a first substrate;
forming a plurality of circuitry and electrodes on a second substrate; and
joining the first and second substrates together with a spacer therebetween by bonding with an adhesive.

64. The method of claim 63, wherein the step of forming the micromirrors on the first substrate further comprises:

coating an opaque layer on the first substrate, wherein the opaque layer is removed before joining the substrates.

65. The method of claim 63, wherein the step of forming the micromirrors on the first substrate further comprises:

depositing a dielectric layer on the first substrate.

66. The method of claim 65, further comprising:
depositing another dielectric layer on the first substrate, wherein said another dielectric layer has an optical index different from that of the dielectric layer.
67. The method of claim 63, further comprising:
dispensing an adhesive around the edge of the first or the second substrate.
68. The method of claim 63, further comprising:
dispensing an adhesive around the edge of the first and the second substrate.
69. The method of claim 63, wherein the step of joining the substrates further comprises:
aligning a pattern on the first substrate to another pattern on the second substrate.
70. The method of claim 63, wherein the adhesive is epoxy.
71. The method of claim 63, wherein the first and second substrates are aligned before bonding.
72. The method of claim 63, wherein the first substrate is a light transmissive substrate.
73. The method of claim 72, wherein the first substrate is glass.
74. The method of claim 72, wherein the first substrate is quartz.
75. The method of claim 63, wherein the second substrate is a silicon substrate.
76. The method of claim 63, wherein the plurality of deflectable elements are formed by depositing a sacrificial layer on the first substrate, depositing one or more deflectable structural layers thereon, and releasing the micromirrors by removing the sacrificial layer.

77. The method of claim 76, wherein the sacrificial layer comprises silicon.
78. The method of claim 76, wherein the sacrificial silicon layer is removed with xenon difluoride.
79. The method of claim 63, wherein the micromirrors are formed of a ceramic material.
80. The method of claim 79, wherein the ceramic material is silicon dioxide or silicon nitride.
81. The method of claim 63, wherein the plurality of circuitry resembles memories.
82. The method of claim 81, wherein the memory array comprises SRAM circuits to drive the electrodes.
83. The method of claim 81, wherein the memories comprises DRAM circuits to drive the electrodes.
84. A method of modulating light, comprising:
providing a spatial light modulator that comprises:
 - a substrate that is transmissive to visible light;
 - a silicon substrate having a plurality of electrodes and circuitry;
 - wherein the silicon substrate and the substrate that is transmissive to visible light are bonded together with a spacer therebetween forming a gap between the substrates; and
 - a plurality of deflectable elements encapsulated within the gap;
providing an incoming light beam that passes through the light transmissive substrate and that is reflected by the electrostatically deflectable elements;

applying a voltage bias between the deformable element and the electrode so as to deflect the deflectable element due to electrostatic attraction; and
deflecting the light beam back through the optically transmissive substrate.

85. The method of claim 84, wherein the deflectable elements are micromirrors, each of which comprising:

a mirror plate having a reflective surface for reflecting light; and
a hinge to which the mirror plate is attached such that the mirror plate is operable to rotate.

86. The method of claim 85, wherein the micromirrors are positioned on the substrate that is transmissive to visible light.

87. The method of claim 85, wherein the micromirrors are positioned on the silicon substrate.

88. The method of claim 84, wherein the silicon substrate is a VLSI-fabricated silicon substrate.

89. The method of claim 84, wherein the circuitry is an addressing circuitry resembling a memory.